Space Weather Technical Forecast

Issued on Sunday, 15 January 2023 at 12:41 Local

This technical forecast provides a four-day assessment of space weather events. The probabilities stated below are for reaching or exceeding the given levels. For more information about space weather impacts please see the Met Office Space Weather Scales https://www.metoffice.gov.uk/weather/learn-about/space-weather/uk-scales

Space Weather Forecast Headline: Further R1/R2 Radio Blackouts Expected throughout. Risk G1 rising from midweek.

Analysis of Space Weather Activity over past 24 hours

Solar Activity: Solar activity has been High over the last 24 hours, with three M-class X-ray flares observed at GOES16. The largest of these events was an M6.0 at 14/0341UTC from emerging region AR3191 on the northeastern limb. Two further M-class flares were observed, with these emanating from AR3182 in the southwest. The first of these was an M3.5 at 14/2006UTC, and the second a peak M4.6 flare at 14/2037UTC. Both of these AR3182 flares were associated with a resulting Coronal Mass Ejection (CME).

The solar disc remains highly congested in terms of sunspot regions, particularly the eastern solar horizon, with eight numbered groups present - including the aforementioned AR3191 and AR3182. AR3189 faded to plage in the past 24 hours in the northwest quadrant, but the population of the disc was otherwise largely maintained with the emergence of up to three additional rapidly-developing, but for the moment small, bipolar regions.

The main sunspots of note on the disc were those containing potential weak Mt Wilson delta spots. i.e. AR3191, 3182 and 3186; as well as the dynamic trends in spots AR3191 and AR3192 in the northeast. Also of merit was recent flare activity in AR3182, despite visually diminishing over this period.

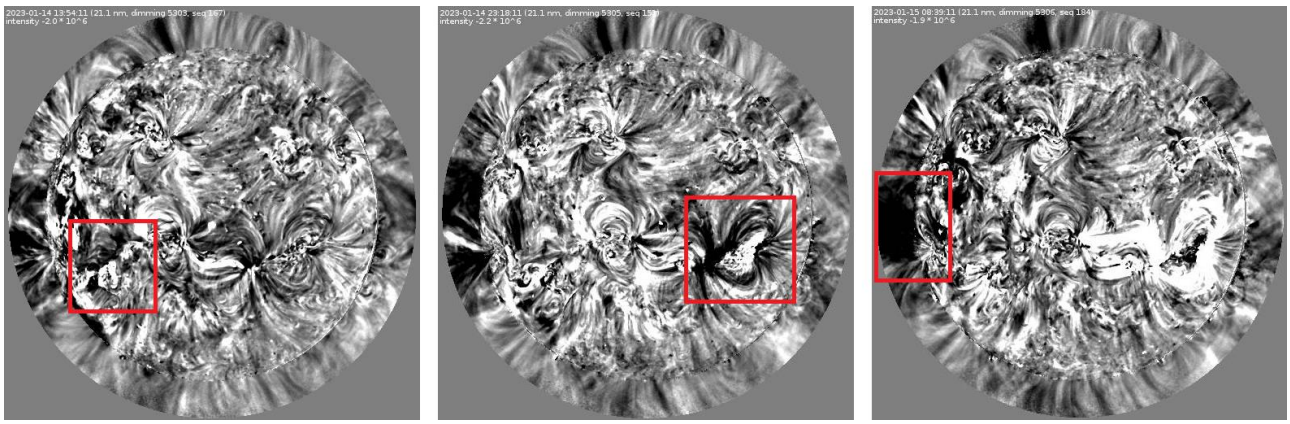


Figure 0: Time-integrated AIA 211 imagery of the most likely three CME-generating events seen on subsequent coronagraph imagery in the 24-hour period (processing courtesy of SIDC ROB). Respectively these are the 14/1246UTC flare, filament and Type II, which has been assessed as a miss; the twin M-class tied CME from near AR3182 around 14/2000UTC – this may affect Earth late on Wednesday 18 January and into Thursday; and finally the 15/0341UTC AR3191 M-flare CME which is pending modelling results but is likely too eastward for any effect at Earth.

Issued by Met Office Space Weather Advisor, Tel: +44 (0) 330 135 4254 Email: moswoc@metoffice.gov.uk

© Crown Copyright 2023. All Rights Reserved.

There were three main events visible in available Lasco imagery in the past 24 hours. Firstly, there was a disappearing filament triggered by activity in AR3188 in the southeast quadrant, with a Type II radio burst and speed estimate of 396km/s at 14/1246UTC. This has been analysed and is a likely miss to no effect at Earth. Secondly, there was a clear partial halo signature associated with a lift off near AR3182 as a result of the two consecutive M-class flares. This feature has been analysed and suggests a risk of affecting Earth at the very end the UTC day of Wednesday 18 January, with effects ongoing into Thursday. Finally, a third visible CME was observed heading largely south and east on Lasco associated with the 15/0341UTC flare, with this feature analysed and MOSWOC Enlil results pending at the time of writing - although provisionally this feature is considered relatively unlikely to present a significant risk.

Solar Wind / Geomagnetic Activity: The solar wind, as measured at L1 by DSCOVR and ACE showed a slight discontinuity in some measures around 14/1700UTC, with subsequent behaviour possibly suggesting the effects of a CME are in course, with this possibly associated with activity on the northwest of the Sun on 11 January, although this link is conjectural. This would follow on the heels of an earlier transient passing L1 from 09 January CME, and the tail of the modest fast wind from CH62/-.

The solar wind speed trace was rather noisy in the 24 hours, but showed a gradual decline from Elevated levels and 500km/s to Slightly Elevated and 450km/s with time. The solar wind density appeared a little above its usual range, with a peak in the low teens ppcc and a flat trend. The main changes in the period were observed in the IMF which underwent a marked change from being small-scale and weakly co-aligned with Earth's field in terms of the north-south component prior to 14/1700UTC, but transitioning to more strongly negative thereafter, with the IMF peaking at 12nT, and the Bz -10 and +5nT. The phi angle showed a gradual drift through negative territory (towards the Sun).

The net result of the above solar wind measures was an increase in activity relative to the preceding 24 hours, with a late revision upwards (after the fact) from a Kp4 to a provisional Kp '5o' in the 00-03UTC interval, else being Quiet to Active.

Energetic Particles / Solar Radiation: The high energy proton flux (greater than 10 MeV) as measured at GOES16 has been very near Background levels, with a very slight enhancement to split the 10MeV band from higher energy protons, although this not even registering 1pfu. The cause is not clearly attributable to any front-side event, and given the slow rise and damped spectrum, may be related to far-side activity.

High energy electron flux (greater than 2 MeV) has varied between Normal Background to Moderate levels on a typical diurnal cycle. The 24-hour integrated electron fluence stayed well below the Active threshold on a steady trend, reaching 3.3e6 integrated pfu by 15/0001UTC.

Four-Day Space Weather Forecast Summary

Solar Activity: Solar activity is Expected to be Moderate, with a daily Slight Chance of X-class flares. Although one of the more active regions departs the front side by midweek UTC, the sheer weight of current and expected eastern solar hemisphere arrivals should serve to compensate, and the trend is flat, all else being equal (i.e. no growth or decay).

Solar Wind / Geomagnetic Activity: Earth is currently experiencing the tail of a fast wind from CH62/-, overlaid with probable 09 January CME influence, and possible 11 January CME influence. All these should fade into the new working week to leave a quieter period in terms of geomagnetism. On day four, Wednesday 18 January, a weak fast wind from CH65/+ may arrive as well as a possible late contribution from the twin M-class AR3182 CME to end the UTC day. The midweek event should represent the peak Chance of Minor Geomagnetic Storm G1 for the period, although much of this risk should follow into Thursday.

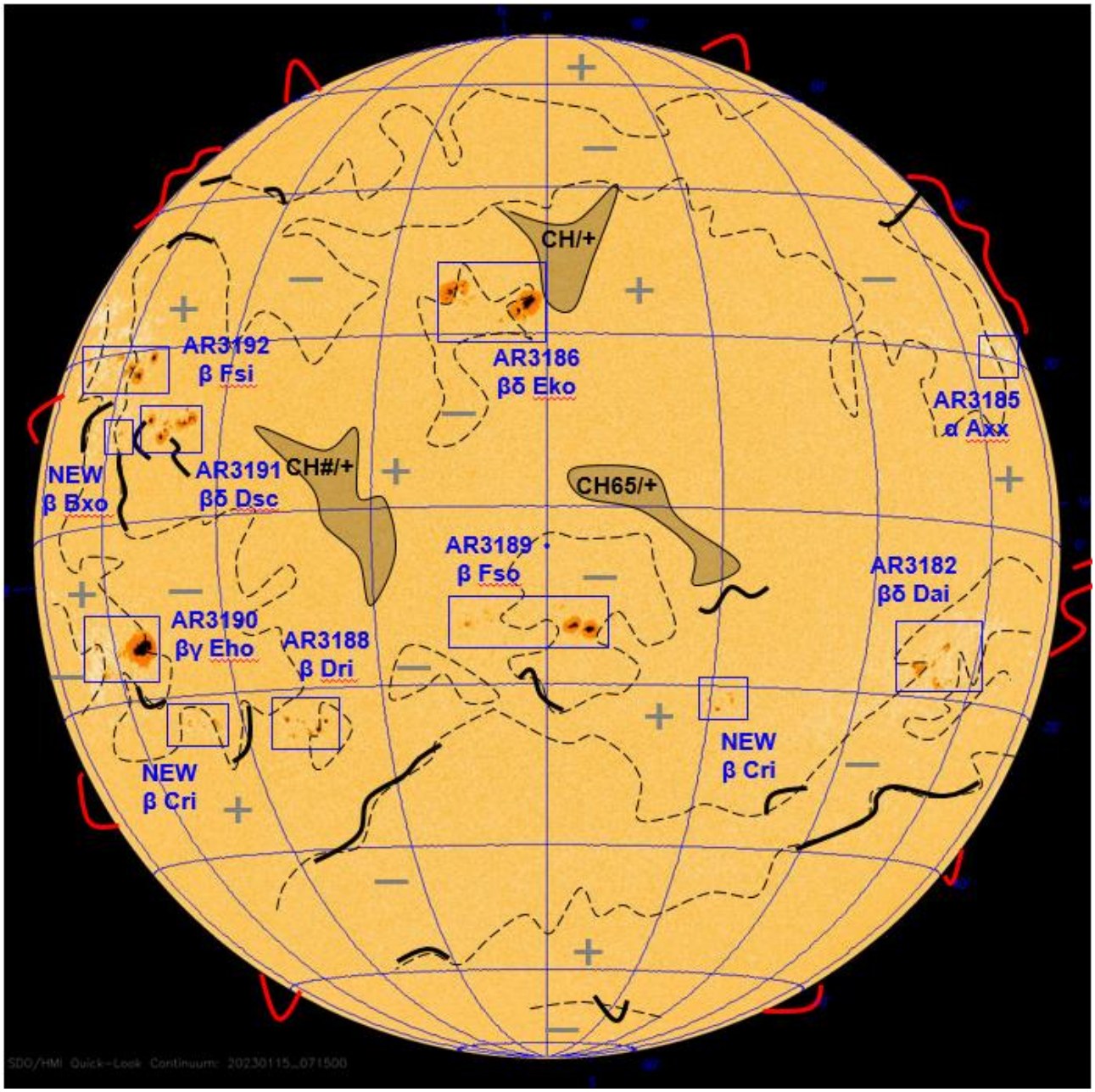
Issued by Met Office Space Weather Advisor, Tel: +44 (0) 330 135 4254 Email: moswoc@metoffice.gov.uk

© Crown Copyright 2023. All Rights Reserved.

Energetic Particles / Solar Radiation: The high energy (greater than 10 MeV) proton flux observed by GOES16 is likely to remain at predominantly Background levels, but with a chance of enhancements which could produce an S1 or greater event through the period due to a number of magnetically complex sunspot regions on the visible disc.

The high energy electron flux (greater than 2 MeV) is expected to continue at Normal Background to Moderate levels, possibly with a slight upward trend, but insufficient for the corresponding electron fluence to breach Active (1e8 integrated pfu).

Figure 1. Solar Analysis Valid 15/0715UTC.



Key: Filament ___ , Prominence ___ , Magnetic Field Line - - - , Polarity +/-, Coronal Holes: Grey shaded area CHxx +/-, Sunspot groups 25xx - Mt Wilson α-β-βγ-βγδ and Zurich-McIntosh Axx etc.

Issued by Met Office Space Weather Advisor, Tel: +44 (0) 330 135 4254 Email: moswoc@metoffice.gov.uk

© Crown Copyright 2023. All Rights Reserved.

Geomagnetic Storms:

This four-day period is bookended by heightened risks of G1 from a combination of fast wind and CME influences in both cases.

Initially, there is the ongoing contribution from the probably 09 January and possible 11 January CMEs on the heels of fading CH62's high speed stream. This has produced a protracted period of negative Bz and an after-the-fact G1 (i.e. a late revision upwards in revised data). Similar is possible but with a reduced probability for the remainder of the UTC weekend, before a largely Quiet environment succeeds this into the new working week.

After this quieter lull, there will likely follow some form of minor fast wind regime from a weakly-defined coronal hole near centre-disc at present, labelled CH65/+. The sheer number of active regions have served to obscure this hole to some extent, but should it survive, MOSWOC Enlil suggests 450-500km/s is feasible on Wednesday 18 January - a suggestion that is tentatively accepted for lack of a suitable analogue from last pass against which to compare it. There is now also a risk of a CME from the AR3182 twin M-flares of 14 January arriving to end the UTC day. This event has formed a clear partial halo in available coronagraph imagery, although the perspective offered by STEREO A against which to triangulate the emission is now of reduced usefulness, with nearly the same viewpoint as at L1.

The above should see an initial Slight Chance of further G1 intervals on day one before a lull, rising to a peak for the period of a Chance on Wednesday 18 January. MOSWOC Enlil suggests the CME midweek is perhaps more likely to arrive in the early hours of Thursday, and the risk of G1 can be expected to rise after the end of this four-day period before falling before the following UTC weekend.

Geo-Magnetic Storm Probability (Exceedance)	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Minor or Moderate	G1 to G2	No	10	1	1	25
Strong	G3	No	1	1	1	1
Severe	G4	No	1	1	1	1
Extreme	G5	No	1	1	1	1

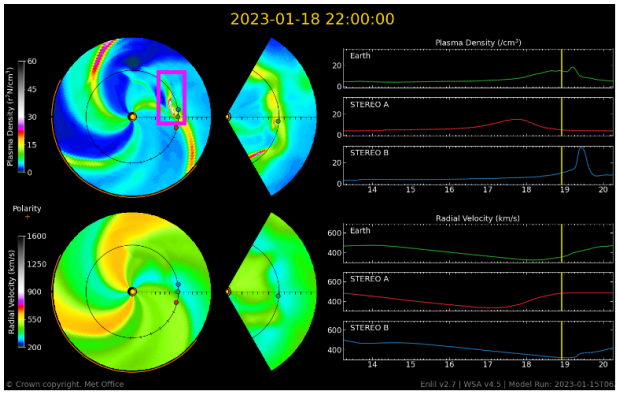
Geomagnetic Activity - Earthbound Coronal Mass Ejections

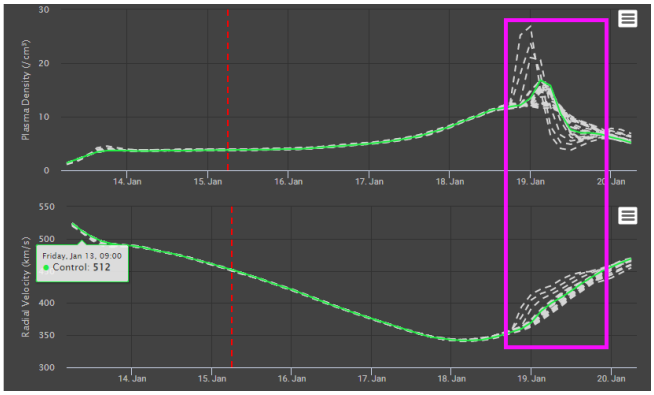
Date/time 21.5R (UTC)	Halo: Full or Partial	Source	Source Location	Estimated Speed	Estimated Arrival Time	Comments
15/0900UTC	Partial	AR3182	SW quadrant	400km/s	Very end UTC day Wednesday 18 January into Thursday	Probable hit, reasonable confidence. Onset time lower confidence.

Issued by Met Office Space Weather Advisor, Tel: +44 (0) 330 135 4254 Email: moswoc@metoffice.gov.uk

© Crown Copyright 2023. All Rights Reserved.

Figure 2: Latest MOSWOC Enlil run and ensemble, showing the 14/2000UTC twin M-class tied CME as possibly geoeffective at the very end of the UTC day of Wednesday 18 January, with the bulk of model members' opinions suggesting early Thursday is more likely.





Radio Blackouts - X-Ray Flares:

Solar activity has been High, and is Expected to be Moderate going forward given the current complex population of sunspot groups on the disc.

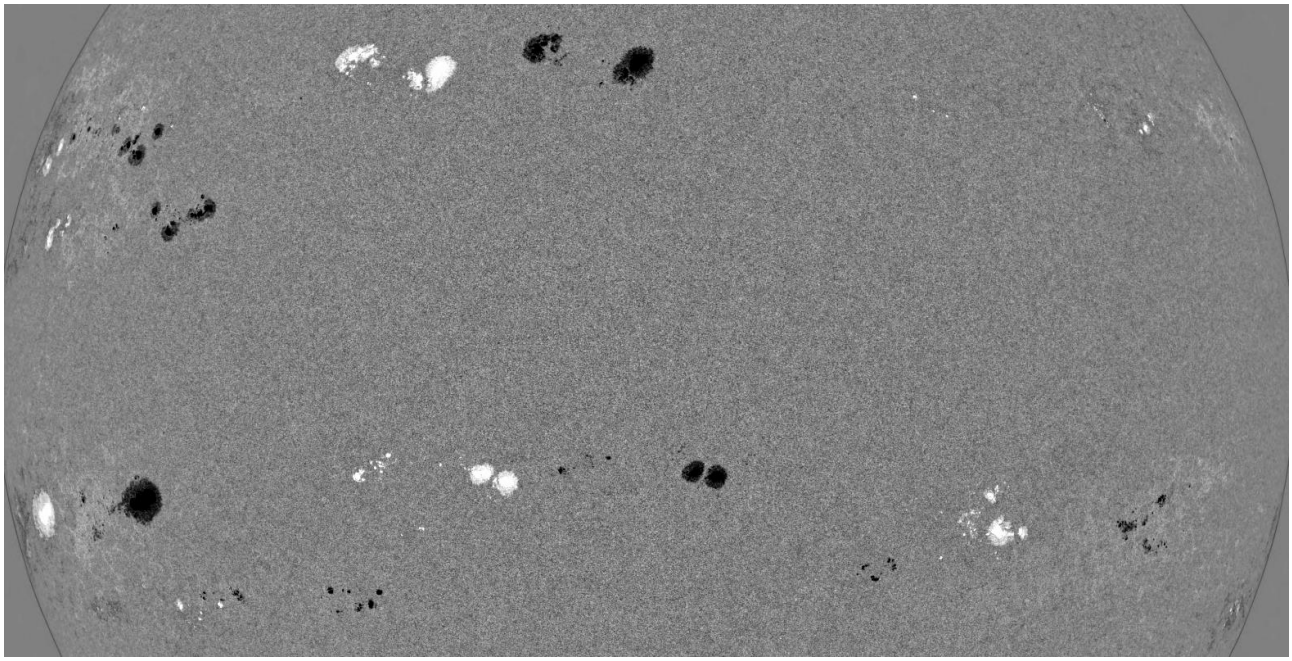
Regarding the balance of front-sided sunspot groups, AR3182 should leave the Earth-facing side by midweek UTC, however the vast majority of major contributors to the flare risk should remain, with these very likely to be joined by further active regions over the eastern solar horizon given evidence on far-side soundings. So, while one noteworthy region does eventually depart, on balance the risk of M-class flares is held constant given the likely feed of compensatory eastern solar horizon spots.

X Ray Flares	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability			(%)	(%)	(%)	(%)
Active	R1-R2 M Class	Yes	80	80	80	80
Very Active	R3 to R5 X Class	No	20	20	20	20

Issued by Met Office Space Weather Advisor, Tel: +44 (0) 330 135 4254 Email: moswoc@metoffice.gov.uk

© Crown Copyright 2023. All Rights Reserved.

Figure 3: Helioviewer.org-generated 36-hour HMIIF footprint difference imagery showing start of UTC weekend (14/0000UTC) in white, and 15/1200UTC in black. AR3191 in the northeast in particular has grown, and AR3182 in the southwest has proven capable of delivering activity despite a shrinking tendency.



Solar Radiation Storms - (High Energy Protons):

The high energy (greater than 10MeV) proton flux is currently very near Background levels, with a very minor soft spectrum enhancement of the 10MeV protons over the past 24 hours or so, with uncertain attribution but possibly far-sided.

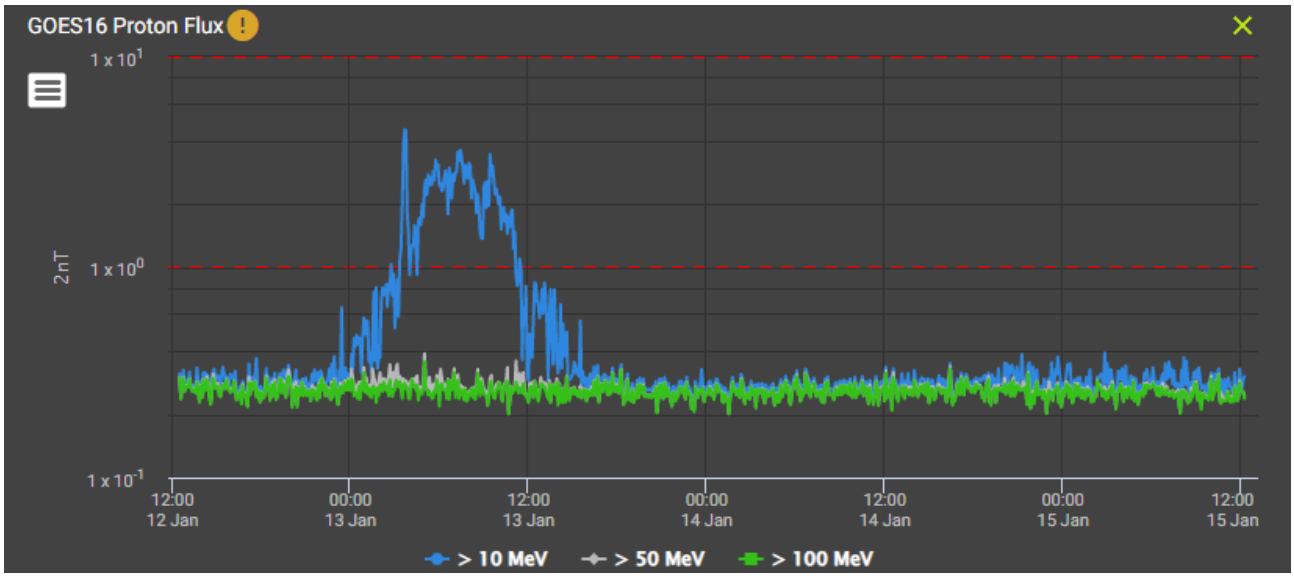
While no recent S1+ events have been observed at GEO, the sheer number of both front and far-sided complex groups dictates a raised risk, with the raw probabilities for the disc as a whole based on their Zurich classes held still higher by the recent presence of Ex-AR3181 on the western limb. While the relative contribution to risk will decrease into the new UTC working week for Ex-AR3181, the weight of sunspot regions in the eastern solar hemisphere will increasingly bring itself to bear, resulting in a relatively constant Chance of S1+ through the four days.

Radiation Storms	**Level (cm^{-2} sr^{-1} s^{-1})**	**Past 24 Hours (Yes/No)**	**Day 1 (00-24 UTC)**	**Day 2 (00-24 UTC)**	**Day 3 (00-24 UTC)**	**Day 4 (00-24 UTC)**
Probability (Exceedance)			**(%)**	**(%)**	**(%)**	**(%)**
Active	**≥ S1**	No	30	30	30	30
Very Active	**≥ S3 ***	No	1	1	1	1
* S3 ≥ 10 MeV ≥ 1000 pfu and / or ≥ 50 MeV ≥ 10 pfu. (pfu = $cm^{-2}sr^{-1}s^{-1}$)						

Issued by Met Office Space Weather Advisor, Tel: +44 (0) 330 135 4254 Email: moswoc@metoffice.gov.uk

© Crown Copyright 2023. All Rights Reserved.

Figure 4: Past three days in GOES16 high energy proton flux, showing modest response to a southwest limb event on 13 January and a very significantly damped and small-scale follow up (possibly from the far side) ongoing into 15 January in greater than 10MeV protons.



High Energy Electrons Event (≥ 2MeV):

High energy electron flux is oscillating between Normal Background and Moderate levels as part of the normal diurnal variation. The recent fast wind from CH62/- is now tailing off and has yet to manifest in any increased magnitude oscillation, however it is more likely than not that it will elicit some form of upward reaction into the new UTC working week. The degree to which this occurs will most likely prove insufficient for 24-hour Active fluence to be realised, given the modest duration and intensity of the fast wind, and the interruption from one and possibly two transients that may have served to redistribute electrons.

Persistence methods are not considered useful in the period given the lack of similarity of the current disc with last pass, as well as the presence of CMEs, however REFM is in agreement in the persistence of a sub-Active trend.

All considered, there is a slightly upward trend possible in flux and fluence, but probably peaking by Tuesday 17 January at the latest and maintaining this level in the absence of any further CME influence.

GEO Electron Environment	**Level (cm^{-2} sr^{-1} day^{-1})**	**Past 24 Hours (Yes/No)**	**Day 1 (00-24 UTC)**	**Day 2 (00-24 UTC)**	**Day 3 (00-24 UTC)**	**Day 4 (00-24 UTC)**
Probability (Exceedance)			**(%)**	**(%)**	**(%)**	**(%)**
Active	**≥ 2 MeV ≥ $1x10^8$**	No	1	10	10	10
Very Active	**≥ 2 MeV ≥ $1x10^9$**	No	1	1	1	1

Issued by Met Office Space Weather Advisor, Tel: +44 (0) 330 135 4254 Email: moswoc@metoffice.gov.uk

© Crown Copyright 2023. All Rights Reserved.